Modeling the Climatic Dependency of Influenza Transmission in the Tropics, Subtropics And Temperate Regions

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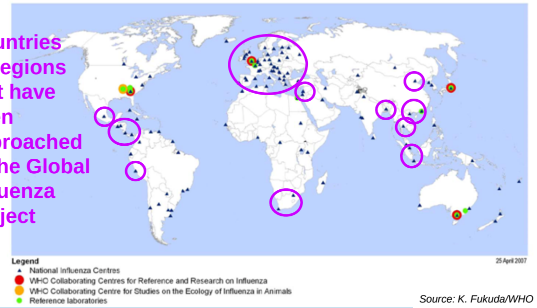
WHO Global Influenza Surveillance Network

Countries or regions that have been approached in the Global Influenza Project



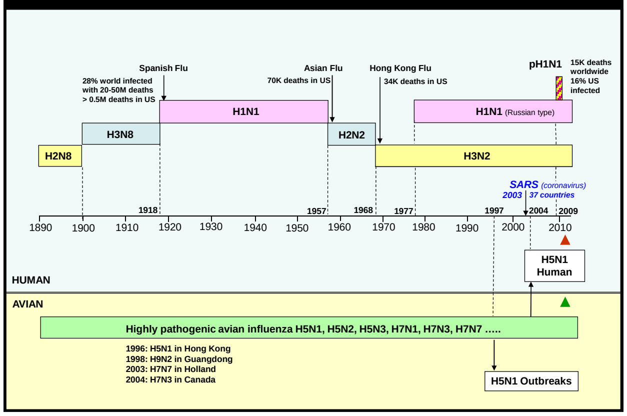
Source: K. Fukuda/WHO

Epidemic and Pandemic Alert and Response

World Health Organization

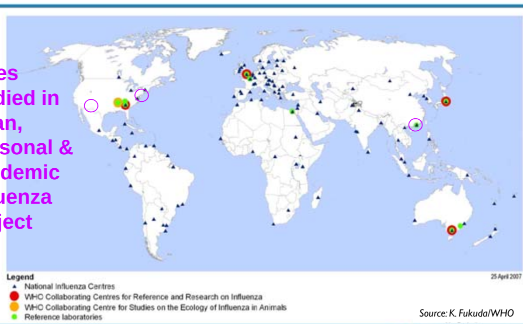
NASA	Avian, Seasonal and Pandemic Influenza
NASA	Modeling Global Influenza Risks
CDC	Modeling Climatic Effects on Seasonal Influenza in WHO EURO Countries
GEO	HE-09-02e International Influenza Transmission
GEO	HE01-C1 Airborne Infectious Diseases

Human & Avian Influenza Epidemics & Pandemics



WHO Global Influenza Surveillance Network

Cities studied in Avian, Seasonal & Pandemic Influenza Project

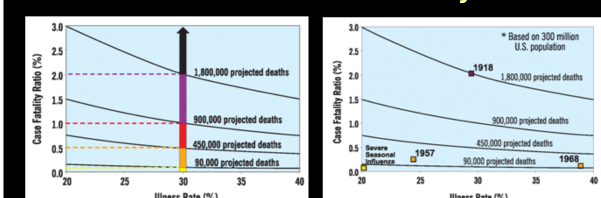


Source: K. Fukuda/WHO

Epidemic and Pandemic Alert and Response

World Health Organization

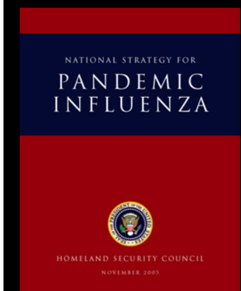
Projected Death in US For Pandemics with Severity 1-5



Category	CFR	Pandemic	Deaths in US
1	< 0.1 %		
2	0.1 – 0.5 %	1918 Spanish Flu	~ 500 K
3	0.5 – 1.0 %	1957 Asian Flu	70 K
4	1.0 – 2.0 %	1968 Hong Kong Flu	34 K
5	> 2.0 %		

Source: USG Prepandemic Plannig Guidance

National Strategy for Pandemic Influenza



THREE PILLARS

- Preparedness & Communication
- Surveillance & Detection
- Response & Containment

OBJECTIVES

- Systematically investigate the effect of meteorological and climatic factors on seasonal influenza transmission
- Understanding influenza seasonality provides a basis on how pandemic influenza viruses may behave
- Develop framework for influenza early warning and pandemic influenza early detection
- Assess and determine the dominating meteorological and environmental factors on influenza incidences at the major population centers
- Using the identified dominant factors, develop climatic-based model to forecast influenza
- Estimate short and mid-term influenza cases at those population centers based on their climatological profiles or climate forecast
- Examine differential sensitivity of the meteorological variables to influenza virus strain types

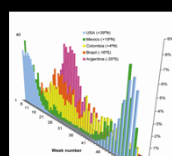
BACKGROUND

- Worldwide annual epidemic

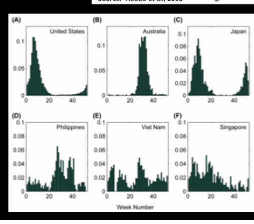
  Infects 5-20% of population with 500,000 deaths
- Economic burden in the US

  ~US$87.1billion
- Spatio-temporal pattern of epidemics vary with latitude

  Role of environmental and climatic factors
- Temperate regions: distinct annual oscillation with winter peak
- Tropics: less distinct seasonality and often peak more than once a year

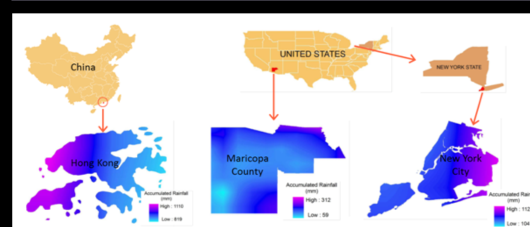


Source: Viboud et al., 2006



Examples

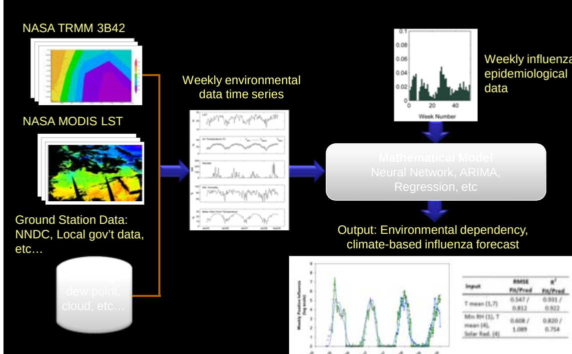
	Hong Kong, China	Maricopa County, AZ	New York City, NY
Center Lat.	22° N	33° N	40° N
Climate	Tropical & Sub-Tropical	Sub-Tropical	Temperate
General Condition	Hot & humid during summer. Mild winter, average low of 6°C	Dry condition. Mean winter low is 5°C, and summer high is 41°C	Cold winter, average low of -2°C. Mean summer high is 29°C



Factors Implicated in Influenza Transmission

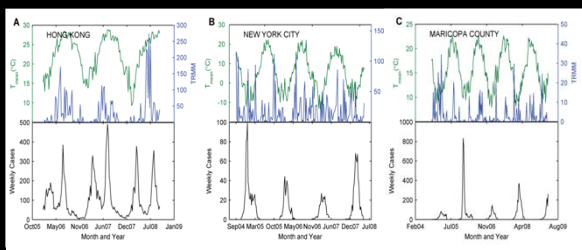
Process	Factors	Relationship
Virus Survivorship	Temperature	Inverse
	Humidity	Inverse
	Solar irradiance	Inverse
Transmission Efficiency	Temperature	Inverse
	Humidity	Inverse
	Vapor pressure	Inverse
	Rainfall	Proportional
	ENSO	Proportional
	Air travels and holidays	Proportional
Host susceptibility	Sunlight	Inverse
	Nutrition	Varies

General Framework



DATA

- Weekly lab-confirmed influenza positive
- Daily environmental data were aggregated into weekly
- Satellite-derived data
  Precipita tion – TRMM 3B42
  Land Surface Temperature (LST) – MODIS
- Ground station data



Role of Vapor Pressure or Absolute Humidity

- Poisson regression model
- Vapor pressure included as input
- Improve model performance in the temperate region

	Vapor Pressure Excluded		Vapor Pressure Included	
	RMSE	R^2	RMSE	R^2
Hong Kong	65.0037	0.593	74.188	0.478
Maricopa County	48.836	0.808	52.946	0.781
New York City	0.0248	0.66	0.0237	0.69

METHODS

Several techniques are employed, including:

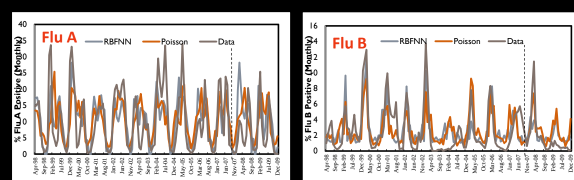
ARIMA (Auto-Regressive Integrated Moving Average)

- Classical time series regression Accounts for autocorrelation and seasonality properties
- Climatic variables as covariates
- Previous week(s) count of influenza is included in the inputs
- Results published in PLoS ONE 5(3): 9450, 2010

Neural Network

- Artificial intelligence technique
- Widely applied for approximating functions, classifications, and pattern recognition
- Radial Basis Function NN with 3 nodes in the hidden layer
- Only climatic variables and their lags as input/predictors

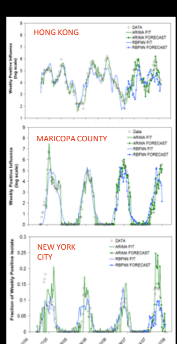
Environmental Sensitivity of Types



	Flu A	Flu B
Inputs	Mean Dew Pt., T min (2), Rainfall (3)	T max (1), Wind Speed, Flu B (2)
RMSE	6.432	1.825
R^2	0.497	0.594

- Flu A does not depend on the number of previous cases
  Environments counts for ~50% of Flu A variability
- Flu B has dependency to previous cases

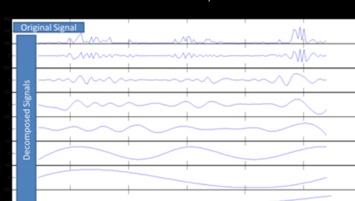
Role of Environments



- NN models show that ~60% of influenza variability in the US regions can be accounted by meteorological factors
- ARIMA model performs better for Hong Kong and Maricopa
  Previous cases are needed
  Suggests the role of contact transmission
- Temperature is a common determinant for influenza in all regions
- Reasonably accurate prediction

Hilbert-Huang Transform

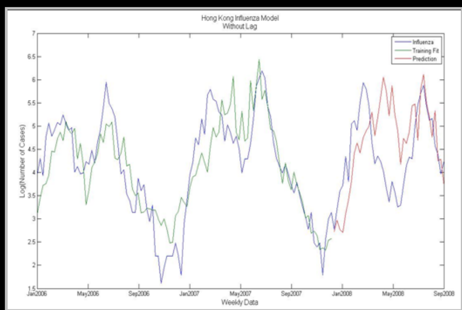
- A NASA developed mathematical technique (Huang et al. 1996) to decompose signal into a finite set of linear and stationary signals – Intrinsic Mode Functions (IMF)
- Complex time series can be decomposed into a finite and often small number of components
  - Applicable to nonstationary and nonlinear processes
  - Broad applications in Earth sciences, engineering, image processing, biomedical sciences, etc.



Example:

Decomposition of TRMM time series

Hong Kong Time Series Modeled with HHT



Input Variables

EVAP (1)
RHMIN (3,5)
TRMM (4)
SUN (4)
CLOUD (6)